NOAA Technical Memorandum NWS WR-119

RELATIVE FREQUENCY OF OCCURRENCE OF WARM SEASON ECHO ACTIVITY AS A FUNCTION OF STABILITY INDICES COMPUTED FROM THE YUCCA FLAT, NEVADA, RAWINSONDE

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June 1977

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RELATIVE FREQUENCY OF OCCURRENCE OF WARM SEASON ECHO ACTIVITY AS A FUNCTION OF STABILITY INDICES COMPUTED FROM THE YUCCA FLAT, NEVADA, RAWINSONDE

Darryl Randerson
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ABSTRACT. A radar echo survey for two warm seasons is used to determine the relative frequency of occurrence of an echo in six selected areas. These areas include the Las Vegas Valley, Lake Mead, and the Spring Mountains, all located in extreme southern Nevada. Also included are the Tonopah and Nevada Test Site areas as well as the Cedar City, Utah, area. The occurrence of an echo in these areas is related to both the K and Z indices, calculated from the Yucca Flat, Nevada, 1200Z sounding. The relative frequency of occurrence of an echo was determined for various categories of K and Z. The resulting charts should have practical value for estimating the probability of the occurrence of moist convection in the specified areas.

I. INTRODUCTION

In a previous study (Randerson, 1976), documentation was provided of the spatial variation of moist convection as detected by Air Route Traffic Control (ARTC) radars in the vicinity of southern Nevada and adjacent areas. The study showed that in some areas of high detectability, approximately twice as much echo activity occurs over high terrain as over the valleys.

In a separate study (Randerson, 1977), both regression analysis and discriminant analysis were used to develop a single-station cumulonimbus (Cb) prediction equation (Z index) for the Nevada Test Site (NTS).[†] Using 10 years of rawinsonde data collected at Yucca Flat, Nevada, regression analysis was used to select the most important predictors to be input to a discriminant analysis program which generated the coefficients for the Z-index equation. The regression equation which selected the predictors accounts for 43% of the variance in the predictand. Based on the same data sample, the K index (George, 1960) explains only

[†] See Appendix A.

33% of the variance of the predictand. Verification of the performance of the Z index on independent data demonstrates it provides a meaningful first approximation to the probable development of local *Cb activity* during the period June through September. In this report, no attempt is made to demonstrate the superiority of one index over the other. The K index is included only because of its popularity and availability.

In this study, both the Z and K values of Yucca Flat are related to the occurrence of *echo activity* as detected by the ARTC radars. Consequently, the spatial variability in the relative frequency of occurrence of moist convection can be determined as a function of an index derived from a single upper-air sounding.

II. PROCEDURE

Hourly radar-echo data were extracted from microfilm records of the Western Region RAFAX transmissions. Only the 1971 and 1972 warm season (June through September) hourly RAFAX charts were surveyed (Randerson, 1976). A total of 238 days were included in the survey. Of these days, 68 were echoless and 10 had missing rawinsonde data.

The grid defined in Figure 1 was used as an overlay to extract the echo data from the microfilm record. Each grid point represents the center of a 28- by 28-km box. The overlay was superimposed on the projected image of each hourly RAFAX chart as it appeared on the screen of a microfilm reader. If *any portion* of an echo appeared within a grid square, an echo was counted as occurring within that square during the specified hour. No effort was made to classify the echo according to intensity or to specify what percentage of each grid box was filled by an echo at a given time. Thereby, the echo inventory only consisted of determining if any portion of an echo occurred or did not occur in a grid square.

Since the objective of the study was to determine if an echo occurred within a specified area during the 24-hour period from local midnight to local midnight, the hourly echo data were summarized for each individual 28- by 28-km box for the 24-hour period. The summarized echo data were printed out in a gridded format to simplify the survey for the daily occurrence of an echo-day.

Warm season echo activity, within the area of Figure 1, goes through a typical diurnal oscillation (Randerson, 1976). Most of the echo activity occurs in midafternoon with minimum activity between local midnight and 0800 LST. Consequently, the echo-day data set does contain some days for which the echo activity occurred before the local 1200Z (0500 LST) sounding was taken; however, the number of these events is small compared with the large number of occurrences between 0500 LST and local midnight. For example, in the Yucca Flat area, only 6 to 7% of the echoes occur between local midnight and the time the 1200Z sounding is taken.

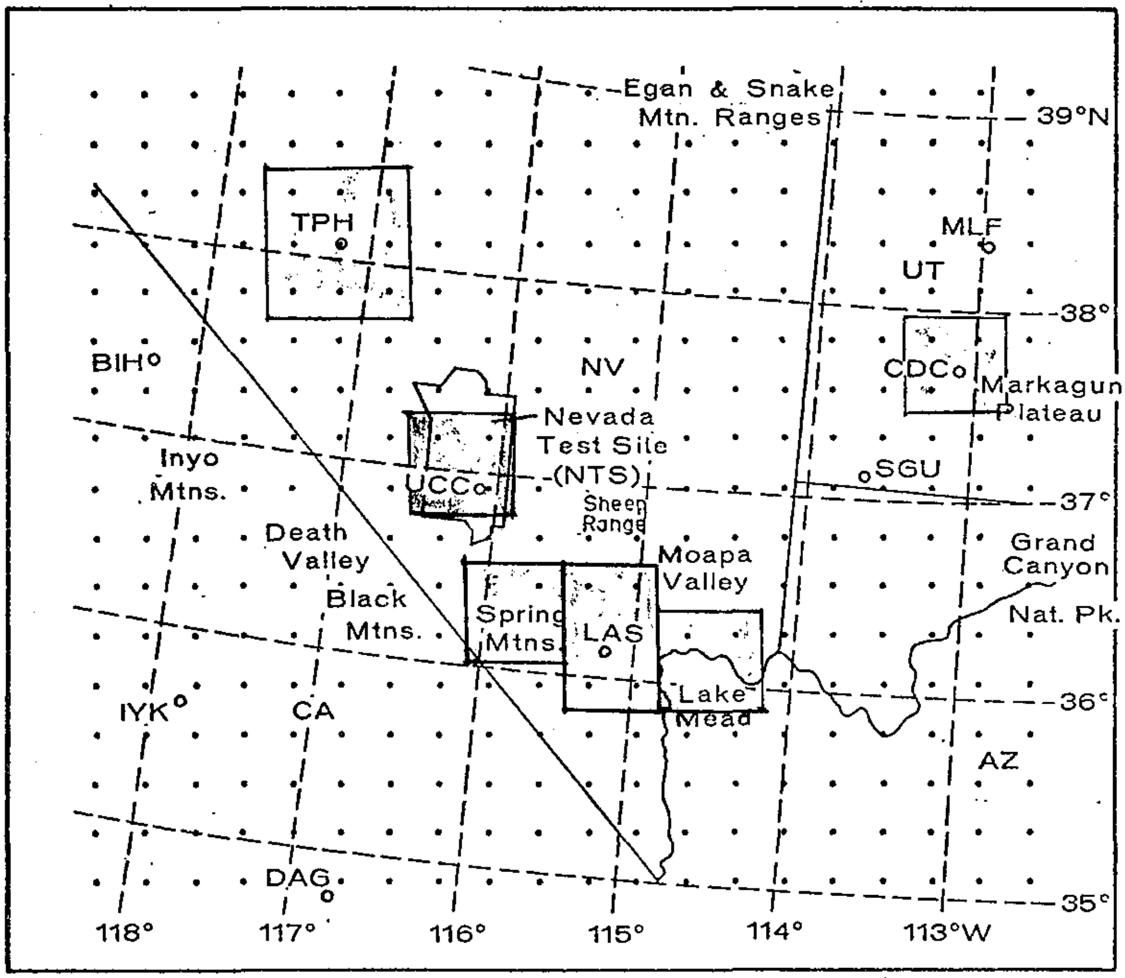

Figure 1. Area considered in the echo survey for southern Nevada and adjacent regions. The shaded boxes represent the specific areas for which the relative frequency of the occurrence of an echo was calculated as a function of both the K and Z indices. Each grid point represents the center of a 28 by 28 km box.

The specific areas surveyed are identified in Figure 1 by shading. These areas were selected primarily for their proximity to regions of high detectability (Figure 2) as well as for population density and recreational use. The Nevada Test Site (NTS) was included because the National Weather Service--Nuclear Support Office (NWS-NSO) is responsible for predicting the weather for this facility.

In Figure 1 notice that the NTS, the Spring Mountains (SPM), Lake Mead (LMD), and the Cedar City, Utah (CDC), areas are all equal in size--3136 km^2. However, the Las Vegas Valley (LAS) covers an area of 4704 km^2 while the Tonopah, Nevada (TPH), area covers 7056 km^2.

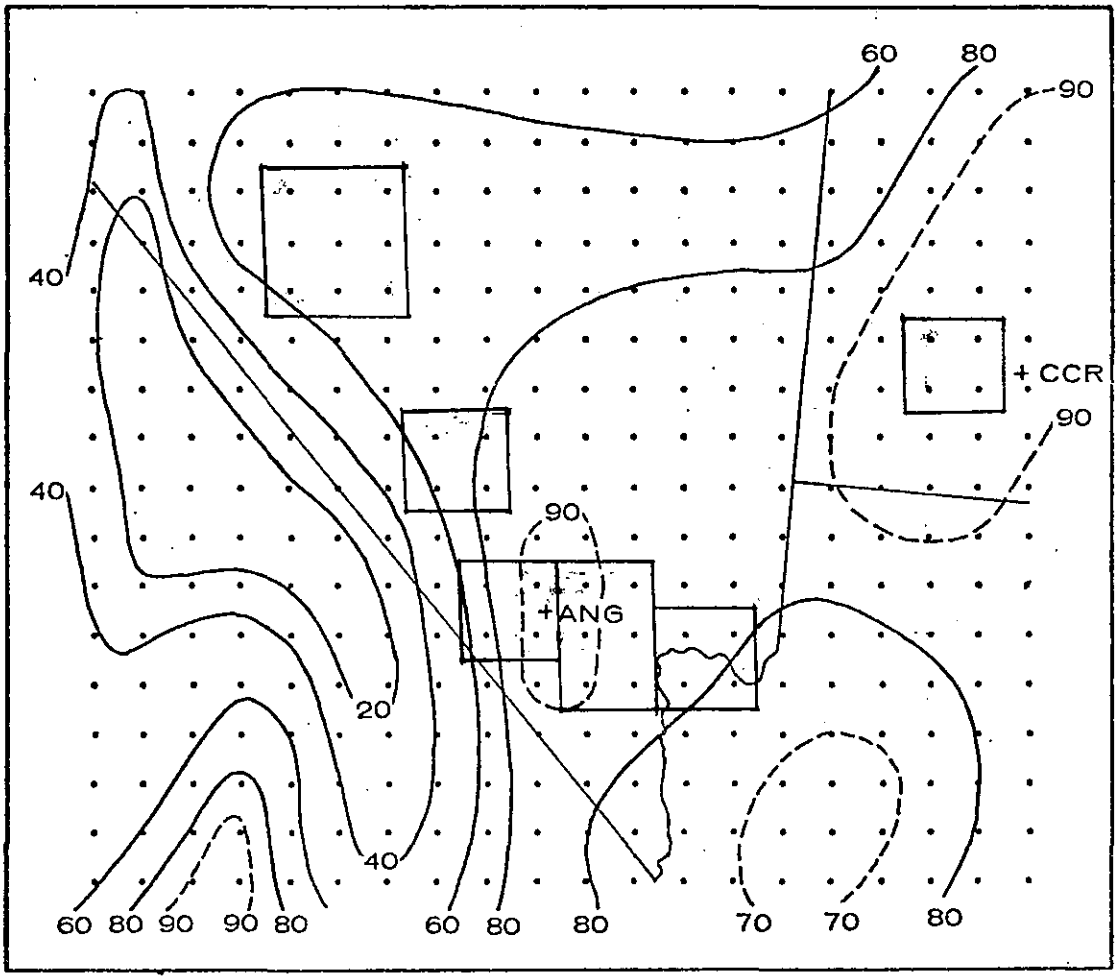

Figure 2. Percentage probability of radar detection of surface precipitation during summertime (from Western Region Technical Attachment 73-11, 3-20-73).

III. RESULTS

Both K and Z indices were calculated from the 1200Z soundings for Yucca Flat. These values were then tabulated along with the echo-day information for each of the six selected areas. Thereby, the relative frequency of occurrence of an echo-day within a given area could be easily computed after summarizing the number of occurrences (and non-occurences) for each of the six areas shown in Figure 1.

The range of the K values was from 40 to -11 while the Z index values ranged from 17 to -5. However, due to the limited number of days with K>35 and <-3, occurrences in these ranges were not used to draw the free-hand curves in Figure 3. These values included four days for K>35 and six days for K<-3. Only two days of Z were not used and these were for Z>15.

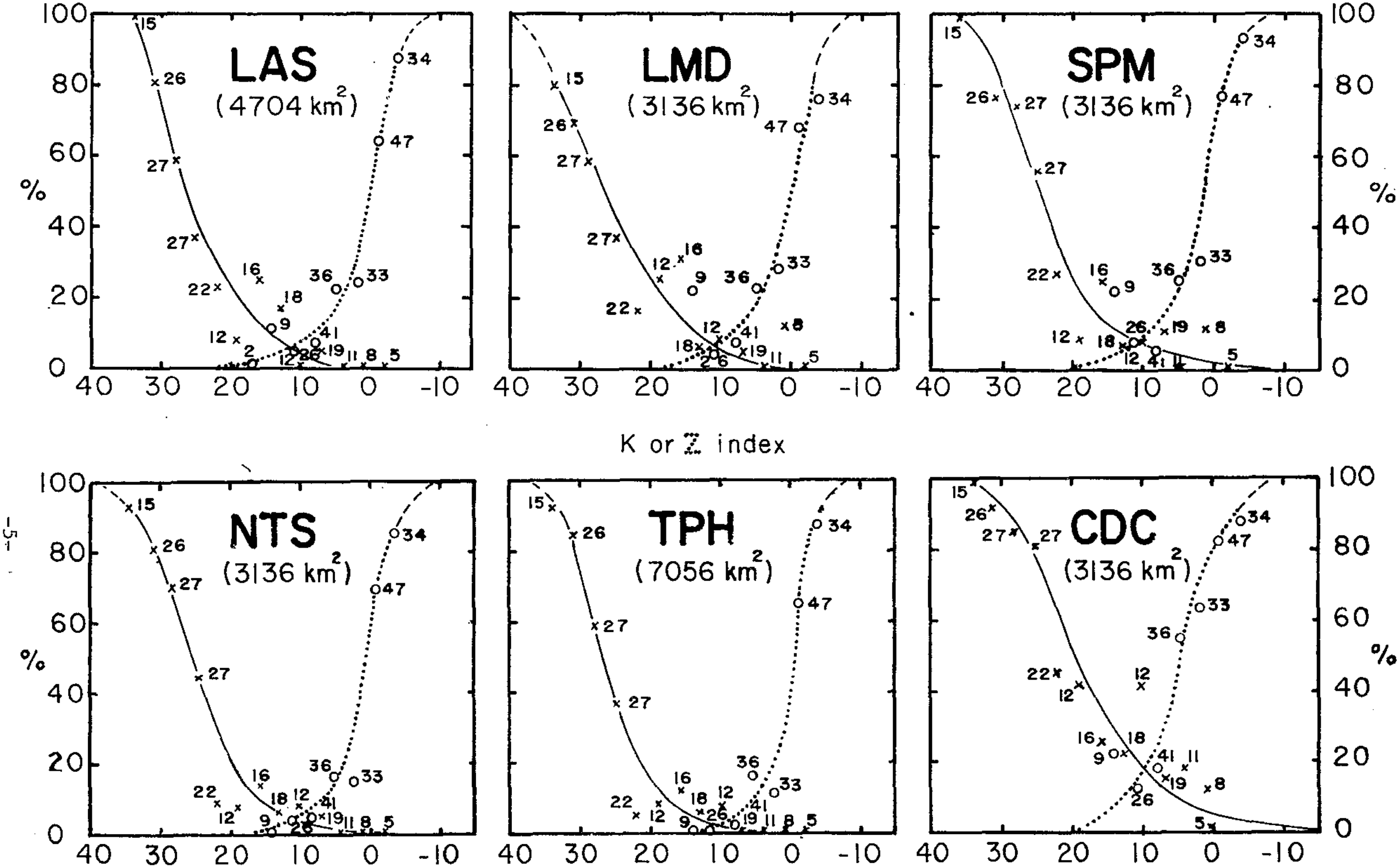

Figure 3. Relative frequency of occurrence of an echo-day for specified areas between local midnight and local midnight as a function of K and Z index values calculated from the Yucca Flat 1200Z sounding. The K curve is represented by the solid line, the Z curve by the dotted line. Values plotted next to the x's are the number of days in each K category and the numbers next to the o's are the number of days in each Z category.

Due to the limited size of the sample, both index values were categorized into groups of three values each. For example, the K index values ranged from K = 34 (includes K's of 35, 34, and 33) to K = -2 (includes K's of -1, -2, and -3). The Z categories ranged from Z = -4 (includes Z's of -5, -4, and -3) to Z = 14 (includes Z's of 15, 14, and 13). Consequently the K values consisted of 13 categories while the Z values contained only 7 categories.

Results of the survey are shown in Figure 3 which represents the relative frequency of occurrence of echo-days as a function of both the K and Z index as calculated from the 1200Z Yucca Flat sounding. The curve of the K index appears on the left-hand side of each chart while the Z curve is on the right-hand side. Both S-shaped curves are free-hand renditions. The values plotted near each data point represent the total number of days in each category. Charts of both indices are presented for the Las Vegas Valley (LAS), the Lake Mead area (LMD), the Spring Mountains (SPM), the Nevada Test Site (NTS), Tonopah (TPH), and Cedar City (CDC).

Caution should be used in interpreting the charts in Figure 3. First, notice the opposing orientation of the indices--negative values of Z correspond with large relative frequencies while large positive values of K correspond with large relative frequencies. Second, the indices are on different scales so that one should not use the slopes of the curves to conclude that one index is superior to the other. The diagrams are presented only to portray the relative frequency of occurrence of an echo-day versus the two different stability indices.

The charts in Figure 3 show that for a Yucca Flat K value of 30, the relative frequency of occurrence for an echo ranges from near 65% for the LMD area to near 95% for the CDC area. For a Z value of 0, the charts show the frequency of occurrence ranges from near 40% for TPH to near 80% for the CDC area.

The relative frequency of occurrence of echo-days as a function of K and Z was also determined for the four grid points in the 90% detectability area in the southwest corner of the grid (Figure 2). This hilly area is in the Mojave Desert. Results indicate that the Yucca Flat, 1200Z, sounding is also representative for this area; however, the frequencies of occurrence are much lower. For example, for a K of 30, the frequency is 40% and for a Z of 0 it is 30%. Comparing these frequencies with those corresponding with the same K and Z values for the other areas helps emphasize the east-west gradient of the frequency of occurrence of moist convection across the area (Figure 1).

Two seasons of echo data is a small sample, especially in a desert area where the yearly variation in moist convection can be large. To add credibility to the small sample, the Z index curve for the NTS was compared with a similar curve developed from a larger data base, but for the relative frequency of occurrence of *Cb days* (Randerson, 1977). The developmental data base used to relate the Z index to Cb days was compiled from the 1200 GMT, Yucca Flat, rawinsonde observations and hourly surface observations taken during 10 consecutive warm seasons (June-September) 1962-1971. The resulting curve for Cb days is not included in the NTS figure because there is little difference between the two curves--both curves would lie approximately on top of each other.

IV. SUMMARY

A description is given of a simple climatological method of determining the relative frequency of occurrence of echo-days for five different areas in southern Nevada and for Cedar City, Utah. The relative frequency of occurrence comes from a radar echo survey of moist convection in the selected areas. The occurrence of echo-days in the selected areas is related to the 1200Z, Yucca Flat, K and Z indices, thereby permitting the frequency of occurrence of echo-days to be computed for various categories of K and Z. The resulting charts should have practical value for estimating the probability of the occurrence of moist convection in the specified areas.

The results confirm that moist convection is observed more frequently over high terrain than over valleys and that in the desert area studied, the frequency with which echoes are observed increases from west to east. Furthermore, the study indicates that upper-air data from a single station are representative of a rather large area, suggesting the grid of rawinsonde stations is adequate.

V. APPENDIX A

The Z-index developmental data set was compiled from hourly surface observations and from the 1200 GMT, Yucca Flat, Nevada (UCC), rawinsonde observations taken in the 10 consecutive warm seasons (June through September) 1962-1971. Out of a possible total of 1220 observational days, 1079 were available for use in developing the Z index. Of these 1079 days, 309 were Cb days and 770 were non-Cb days. For the UCC weather station, this 10-yr sample shows that approximately 70% of all the Cb days (includes thunderstorm days) occur during the period June through September.

The dependent variable, Cb days, was catalogued from the hourly surface observations for UCC. Corresponding independent variables (predictors) were selected from only the 1200 GMT rawinsonde data. Consequently, an implicit assumption in the Z index is that the basic vertical structure of the atmosphere remains unchanged throughout the corresponding day. The potential predictors were temperature, dew-point depression, dew-point temperature, u and v components of the wind, height (station pressure for the surface), the K index, the Total Totals index (Miller, 1967), and the SWEAT index (Bidner, 1971). The variables were specified for the surface (near 880-mb level) and for 50-mb intervals from the 850-mb level through the 500-mb level.

To select the set of predictors for input to the discriminant analysis program, all the data were input to a regression analysis routine (WRAP) so that the variables would be selected objectively. Using the number of hours of Cb activity as the dependent variable, the

WRAP program scanned the independent data and calculated the reduction in the regression sum of the squares that would occur as each independent variable was deleted from the analysis. The minimum reduction in the regression sum of the squares was then determined and divided by the error sum of the squares--a ratio that has an f distribution. This value of f was tested against the 95% probability level. This probability level was used in deleting variables from the regression and it can be expressed as the area under the f curve from zero to f_o, where f_o is the significant value of f. If the value was not significant, that independent variable was deleted from the analysis and the process repeated until the deletion of an independent variable would have resulted in a significant reduction of the variance explained. This selection process ended with nine predictors remaining. The resulting regression equation accounts for approximately 43% of the variance of the predictand. Based on the same data sample, the K index explains only 33% of the variance of the predictand. The nine predictors selected from the rawinsonde data were the surface pressure, surface temperature, surface dewpoint depression, 850-mb temperature, 800-mb dew-point depression, 700-mb height, 500-mb temperature, 500-mb dew-point temperature, and the u component of the 500-mb wind. Notice that the K, Total Totals, and SWEAT indices were all rejected by WRAP.

After objectively selecting the predictors, one is tempted to attribute some physical significance to the selected parameters and to offer physical reasons why other variables remain unselected. However, such an analysis is difficult to make and any conclusions reached are subject to question because of the inherent redundancy in the informational content of meteorological data.

The data for the nine predictors (v_i) were input to a discriminant analysis program which computes coefficients (a_i) of the linear function,

$$Z^* = a_1v_1+a_2v_2+\ldots+a_nv_r$$

such that the difference between an average Z* for non-occurrences and an average Z* for occurrences is a maximum. Unfortunately, the discriminant analysis program was limited to a sample size of not more than 300 cases in each of the two groups (occurrence and non-occurrences). The first 300 cases in each group were selected from the data base and run with the nine predictors selected by WRAP to produce the coefficients for the linear discriminant function, Z*. The resulting regression equation for Z*, is

$$Z^* = 165.19V_1 - 14.63V_2 + 11.73V_3 + 31.52V_4 + 38.22V_5 - 17.30V_6 + 85.89V_7 + 12.69V_8 - 12.85V_9 \qquad (1)$$

where,

V_1 = surface pressure (mb)

V_2 = surface temperature ($^\circ$C)

V_3 = surface dew-point depression ($^\circ$C)

V_4 = 850-mb temperature ($^\circ$C)

V_5 = 800-mb dew-point depression ($^\circ$C)

V_6 = 700-mb height (m)

V_7 = 500-mb temperature ($^\circ$C)

V_8 = u component of the 500-mb wind (kts)

V_9 = 500-mb dew-point temperature ($^\circ$C)

The data base used to derive Eq. 1 consisted of 309 occurrences (Cb days) and 770 non-occurrences so that the 300 occurrences came from essentially the entire data base. However, the first 300 non-occurrences included that portion of the data base from 1 June 1962 through 24 June 1966. The discriminant analysis program ranked these 600 cases in descending order and each case was identified as corresponding to an occurrence (YES) or non-occurrence (NO) of a Cb day. Using the ranked index values and collecting these values into groups of 100 cases each, the relative frequency of occurrence of a Cb day was computed for each group. One overlapping group of 100 cases was added near the 57% level to provide a data point near the inflection point of the curve in Figure 4. The percentage of the YES cases was plotted at the median value of the Z index for each group of 100 cases. Plotted values yield an S-shaped curve which was drawn freehand to produce the subjective curve in Figure 4. This curve allows you to determine the relative frequency of Cb activity being observed at some time during the day based on information available in the 1200 GMT UCC sounding on that day. When applied to a forecasting situation, the Z index provides a first approximation to the probability of moist convection occurring on the given day.

In Figure 4, the values of Z* have been modified by use of the expression

$$Z = 0.01\ (Z^* - 93200) \tag{2}$$

so that for a relative frequency (probability, P) of 50%, $Z = 0$. In addition, for probability levels greater than 50%, Z will be negative. In general, for $Z<-4.0$, $P>90\%$ and for $Z>5.0$, $P<10\%$.

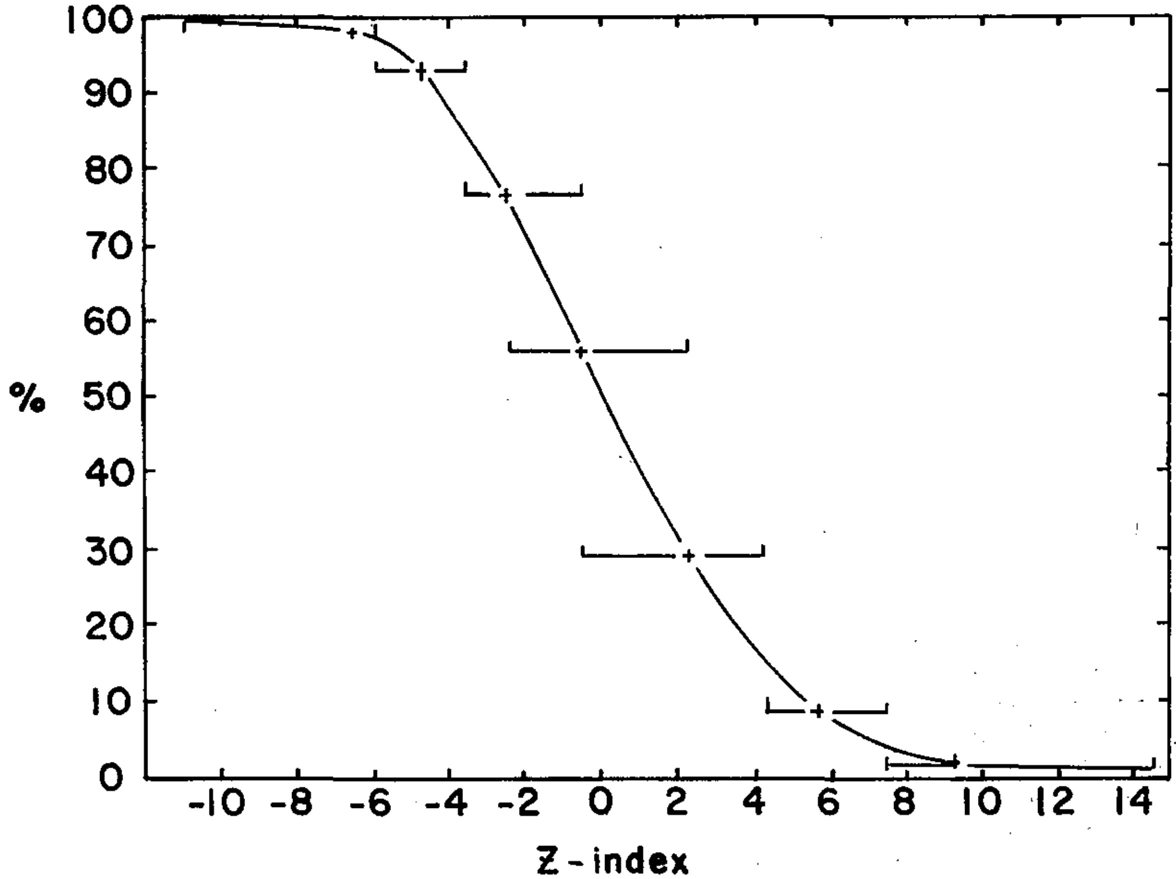

Figure 4. Z index versus the percentage frequency of occurrence of a cumulonimbus cloud being observed in the vicinity of the NTS. Each + point represents the median Z value contained within groups of 100 ranked Z values. The range of the 100 Z values in each group is represented by lines paralleling the abscissa.

VI. ACKNOWLEDGMENTS

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